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The University of Minnesota's Biological Sciences Laboratory

Summary

The retrocommissioning of the University of Minnesota's 207,115-square-foot Biological Sciences laboratory is an outstanding example of a modest efficiency investment that delivered strong financial performance. Completed for a cost of only $450,000, the project yielded a 46 percent reduction in weather-normalized energy use intensity (or EUI, defined as a building's site energy use per gross square foot of building area). IMT calculates that the project's primary efficiency measures had an associated net present value of $1,582,881 and an 80 percent internal rate of return. The annual return on investment was approximately 60 percent, which equates to a 596 percent total return on investment when considering the assumed 10-year useful life of the efficiency measures. While operating expense savings were the primary benefit of retrocommissioning, the project also improved occupant comfort and other measures of building value.

Courtesy the Regents of the University of Minnesota

Figure 1: **Exterior of Biological Sciences on St. Paul campus.**

"We implement energy conservation projects as a key component of the University's sustainability goal of becoming carbon neutral by 2050."
—Blaine O'Brien, Senior Energy Auditor

Lessons Learned

- Aligning building system operations with occupancy trends can yield considerable utility savings.
- Decreasing the rate at which outdoor air is brought into a building can significantly reduce the amount of energy needed for heating, especially in cold climates.
- For property owners in the "MUSH" market (municipalities, universities, schools, and hospitals), facilities with high energy use (measured by EUI) within portfolios can be good candidates for retrofits.
- Not all retrofits are expensive or coincide with capital-intensive events (such as sale, refinance, renovation, or repositioning), and this is particularly true of retrofit measures tied to retrocommissioning.

Background

As part of its commitment to sustainability, the University of Minnesota has undertaken ongoing efforts to improve the energy efficiency of its campus buildings. To help carry out this mission, the University's Energy Management Group has

been proactive in reducing energy consumption across campus. The University spends approximately $100 million annually on energy, and each year the Energy Management Group tries to reduce this expense by approximately 5 percent across the University's portfolio. Two areas of work keyed the group's efforts: retrocommissioning and education, where retrocommissioning refers to the process of improving the operation of building equipment and systems, with the goal of optimizing existing building performance. The department also educates students, faculty, and staff on the various benefits of energy efficiency, in order to increase awareness of this important issue and encourage energy-efficient occupant behavior.

The Energy Management Group's main focus for improving building efficiency is its Building Retrocommissioning Program, which began in 2004. The program follows a series of activities for each building project, including:

- Testing mechanical and electrical systems, and making repairs as necessary
- Optimizing building systems' operation based on building use and schedules
- Identifying Energy Conservation Opportunities (ECOs) that require both minimal and significant capital investment
- Calculating the likely return on investment for each ECO

Building Information

Owner: University of Minnesota

Location: Falcon Heights, Minnesota

Building Type: Teaching and research laboratory

Size: 8 stories; 207,115 square feet

Year Built: 1969

After completing these tasks, the Energy Management Group can make well-informed decisions regarding which ECOs to ultimately implement. Once the retrocommissioning work has been undertaken, the final critical step is to repeatedly evaluate the project's actual energy and cost savings, as well as other project benefits such as increased occupant comfort.

When describing the motivation behind the building retrocommissioning efforts, Blaine O'Brien, a Senior Energy Auditor for the University, mentioned, "We implement energy conservation projects as a key component of the University's sustainability goal of becoming carbon neutral by 2050. To achieve this goal we can either start in 2048 frantically installing solar panels everywhere, or we can start making incremental changes today."

The Project

Constructed in 1969, Biological Sciences is a dual-purpose teaching and research laboratory with eight floors and 207,115 square feet, located on the University's St. Paul campus. No significant efficiency improvements were made to Biological Sciences in the years preceding the recent retrocommissioning effort, which began in June 2013 and concluded in January 2014.

While the University's Energy Management Group has hired external contractors in the past, O'Brien, who managed the retrocommissioning of Biological Sciences, noted that his team has had greater success using University personnel and resources, as was the case with this project. For this retrocommissioning project, the team consisted of O'Brien, an electrican, and three HVAC technicians. The electrician helped install wiring, while the technicians were responsible for taking air readings, as well as managing the air handlers and water piping systems. Before the team began the retrocommissioning work, it organized a series of "lunch and learns" with the building's occupants to make them aware of and seek their input on the proposed energy efficiency measures.

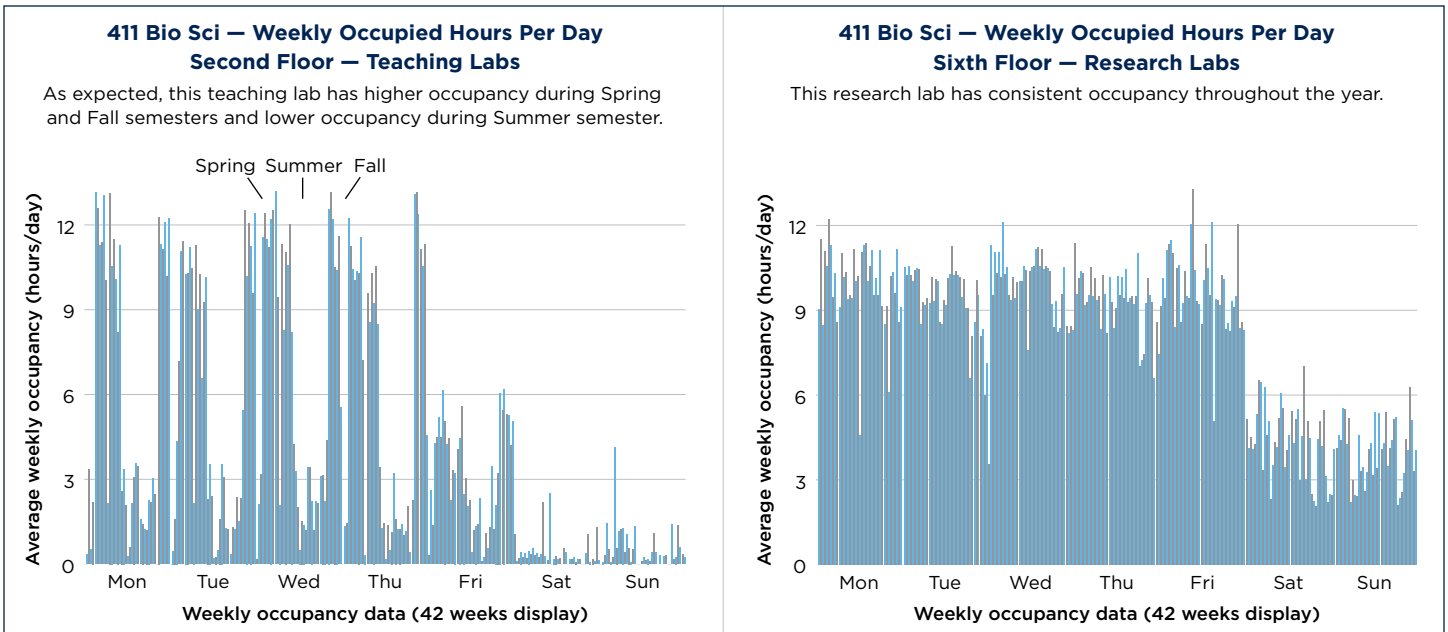


Figure 2: **Weekly occupancy data for a second floor teaching lab (left) and a sixth floor research lab (right).**

The Energy Management Group identified Biological Sciences (and other campus buildings in need of retrocommissioning) using the Energy Use Intensity (EUI) metric, defined as a building's site energy use per gross square foot (GSF) of building area. While the University targets an annual EUI of less than 200 kBtu/GSF for each of its laboratory buildings, Biological Sciences had an average annual EUI of 339 kBtu/GSF from 2006 to 2011, making it a priority for retrocommissioning.

Efficiency Measures

Occupancy Analysis. The Energy Management Group reduced Biological Sciences' energy use by analyzing the building's occupancy patterns. By installing occupancy sensors in all laboratory spaces—a cost-effective best practice—the team was able to identify a critical operational change that would improve the building's energy efficiency.

Building occupancy is illustrated in the two graphs of Figure 2, which depict weekly occupancy data for a teaching and research laboratory, respectively. During the Spring and Fall academic semesters, the teaching lab is occupied approximately 12 hours a day, Monday through Thursday. It is occupied for only about half that time on Fridays, and significantly less on the weekend when classes are not as common. The teaching lab is used much less often during the Summer semester, when fewer classes are offered.

Unlike the teaching lab, the research lab is occupied consistently throughout the year, with no noticeable drop off during the summer semester when students and professors alike remain on campus to conduct research. The research lab's weekend occupancy was lower than its weekday occupancy, although this difference was not as pronounced as the difference between the

Efficiency Measures

- Occupancy sensors in all laboratory spaces
- Variable Frequency Drives (VFDs) provide 6 ACH during the day and 3 ACH at night
- Two-way hot water system replaced existing three-way system
- Reheat system turned off during summer months
- 500 LED kits installed throughout building

Figure 3: **Key components of Biological Sciences' retrocommissioning plan: an installed VFD (left), hot water coils (middle), and a dimmable LED in a stairwell (right).**

teaching lab's weekend and weekday occupancy.

The key takeaway from these two graphs is that they both have a significant amount of white space, which represents the length of time the labs are unoccupied. Based on this observation, the Energy Management Group saw a great opportunity to reduce the amount of conditioned outside air delivered to these labs, and other rooms in Biological Sciences, while they are not in use.

Mechanical Ventilation. When Biological Sciences was constructed in 1969, building mechanical systems were designed to provide 16 to 20 air changes per hour (ACH). In other words, every hour, air within the building was being replaced approximately 18 times without regard for the energy use required for this high level of ventilation. Generally speaking, buildings with higher air change rates require more energy, both to circulate and condition the incoming outdoor air. For the University of Minnesota, which is located in a cold climate, Biological Sciences' outdated air change rate led to substantial energy costs, as a large amount of energy was needed to heat the incoming air.

The retrocommissioning project's primary goal was to reduce Biological Sciences' air change rate from its pre-retrocommissioning level of 12–14 ACH to around 6 ACH, a more appropriate level based on modern day recommendations and the building's occupancy. A team technician first took air readings of all eight fans supplying outdoor air to the building to determine the existing air change rate. After analyzing the air readings and undertaking additional due diligence, the team installed variable frequency drives (VFDs) on each fan motor to regulate the incoming building air flows. The Energy Management Group was able to achieve significant energy and cost savings, while maintaining acceptable ventilation levels for indoor air quality purposes, by setting the VFDs to provide 6 ACH during the day and just 3 ACH at night, when the building is unoccupied.

Financial Performance

The budget for the Energy Management Group's retrocommissioning program varies depending on the University's overall budget, but it is generally around $2.5 million annually. Funding for the retrocommissioning of Biological Sciences came exclusively from this program's budget—there was no external financing—and the University spent approximately $450,000 on the project, which was inclusive of both capital improvement costs and staff time.

Of the total $450,000 spent on the project, detailed costs were as follows: the total cost of installing the VFDs was $132,000, which was

primarily divided between the electrician's labor and the motor replacement costs. Installing the VFDs resulted in annual savings of $106,000 and thus a simple investment payback of 1.2 years. An additional $187,000 in costs were necessary to reduce the incoming outdoor air flow—these expenses were incurred for sheet metal work and to pay the balancer who took the air readings. These additional measures yielded a combined $136,000 in annual savings, equivalent to a simple payback of 1.4 years. The remaining project expenses were incurred for various smaller tasks, such as replacing lamps throughout the building.

While the simple paybacks calculated above may provide reasonable approximations for the break-even points of the efficiency measures, a discounted cash flow (DCF) analysis is a more sophisticated financial assessment and is the preferred method for calculating the value of energy efficiency measures. Before applying a DCF analysis to the retrocommissioning of Biological Sciences, IMT made the following assumptions:

- Useful life of 10 years for efficiency measures[1]
- 8 percent discount rate[2]
- Local energy prices will rise approximately 4 percent annually[3]

Based on these assumptions, the net present value (NPV) and internal rate of return (IRR) of the retrocommissioning project's two primary efficiency measures were $1,582,881 and 80 percent, respectively. The associated annual return on investment (ROI) was 60 percent, which equates to a total ROI of 596 percent over the assumed 10-year useful life of the efficiency measures.[4]

Property Value

As Biological Sciences is owned by a public institution, some drivers of value for tenanted high-performance buildings, such as greater occupancy and revenue, do not apply to this project. However, the retrocommissioning did achieve a demonstrated reduction in operating expenses, which conveys significant value to the University. The project's two primary efficiency measures had an associated NPV of $1,582,881, which translates to $7.64 per square foot of value created for the building. This value increase is nearly five times greater than the $1.54 cost per square foot invested in these efficiency measures.

"This project validated for us that recommissioning is an integral part of getting to our ultimate goal. It's one of the tools we have to get there."

—Blaine O'Brien, Senior Energy Auditor

Conclusion

The retrocommissioning of Biological Sciences was a tremendous success, yielding a substantial return on the University's investment and a 46 percent reduction of the building's weather-normalized annual EUI. Biological Sciences is now one of the most energy efficient teaching and research laboratories on campus, and the Energy

1 The useful life of the VFDs was estimated to be 10 years. While sheet metal is a durable material and the incoming outdoor air flow could be kept low for a long period of time, the useful life for this efficiency measure was conservatively estimated as 10 years, as well.

2 This discount rate is estimated to be 100–150 basis points higher than the local market cap rate, which was estimated by a local appraiser who considered the building type, occupancy type, and building location.

3 According to the Energy Information Administration, electricity prices increased by 21 percent in Minnesota from 2008–2013, which corresponds to a 4.2 percent annual increase. This value was also used as a conservative estimate for annual increases in local natural gas and water prices.

4 IRR is the discount rate that sets the NPV = 0. In other words, it's the discount rate associated with the break-even point of the investment. Annual ROI is equal to the average annual savings (present value/useful life) divided by the upfront investment cost.

Management Group plans to undertake additional measures to improve the building's efficiency in the future. While describing the project, Senior Energy Auditor Blaine O'Brien again referred to the University's mission of becoming carbon neutral by 2050, noting that "this project validated for us that retrocommissioning is an integral part of getting to our ultimate goal. It's one of the tools we have to get there." The University's Energy Management Group is encouraged by the project's outcomes and seeks to apply what was learned with Biological Sciences to other campus buildings. This could entail both revisiting buildings that have already been retrocommissioned and exploring new retrocommissioning opportunities.

Appendix A. Additional Measures

While significantly reducing the building's air change rate was the primary objective of the retrocommissioning project, other measures were also undertaken to make Biological Sciences more energy efficient. The team converted the hot water system from a three-way to a two-way system. While the hot water pump runs continuously in both setups, the advantage of the two-way system is that the speed of the pump can be controlled by a differential pressure sensor. The ability to decrease the speed of the pump when there is less demand for hot water resulted in significant energy savings for the building.

In addition, the 25-year-old valves on several of Biological Sciences' individual reheat units began to fail in the years prior to retrocommissioning, ultimately leading to simultaneous heating and cooling in many rooms throughout the building. Replacing these valves was deemed too costly an investment, so instead this issue was resolved by turning off the building's reheat system in the summer months, except on humid days.

Finally, approximately 500 energy-efficient light-emitting diodes (LEDs) were installed throughout the building to improve light quality and reduce electricity consumption. Other measures such as adding insulation and replacing windows were not considered due to their relatively long paybacks.

Appendix B. Results

The four graphs in Figure 4 reveal the substantial impact that the retrocommissioning project had on the performance of Biological Sciences. The graph of steam usage clearly shows that retrocommissioning had an immediate positive effect, as the building's steam consumption was lower than expected beginning in June 2013, the month retrocommissioning commenced. Turning off the reheat system decreased unnecessary steam use during the summer, while reducing the air change rate led to lower steam consumption in the winter.

The retrocommissioning project also had a substantial impact on Biological Sciences' electricity consumption, although not quite as large as its effect on steam usage. While electricity demand was reduced slightly with the installation of energy-efficient LEDs, the investment in VFDs had a much larger effect by limiting the electricity needed to power the supply air fans and hot water pumps. While monthly electricity consumption exceeded 400,000 kWh several times in 2012, it was primarily below 300,000 kWh in 2014.

In addition to energy savings, the retrocommissioning effort also substantially reduced the demand for chilled water, which is used to cool

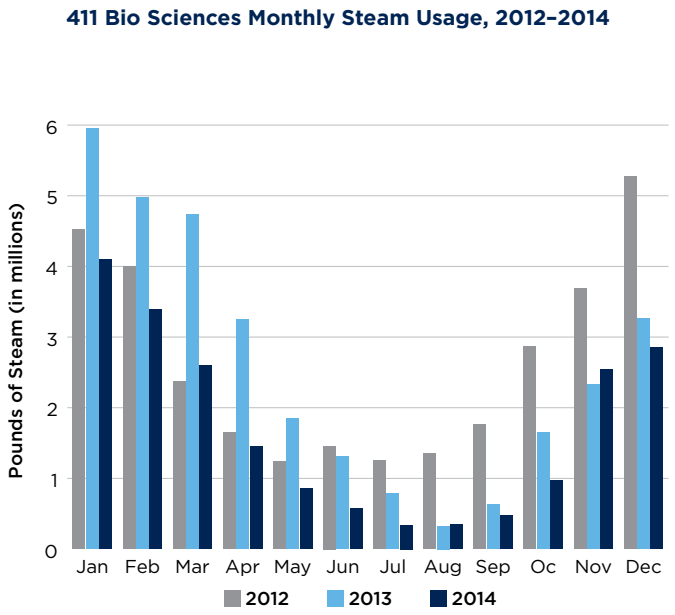
Key Results

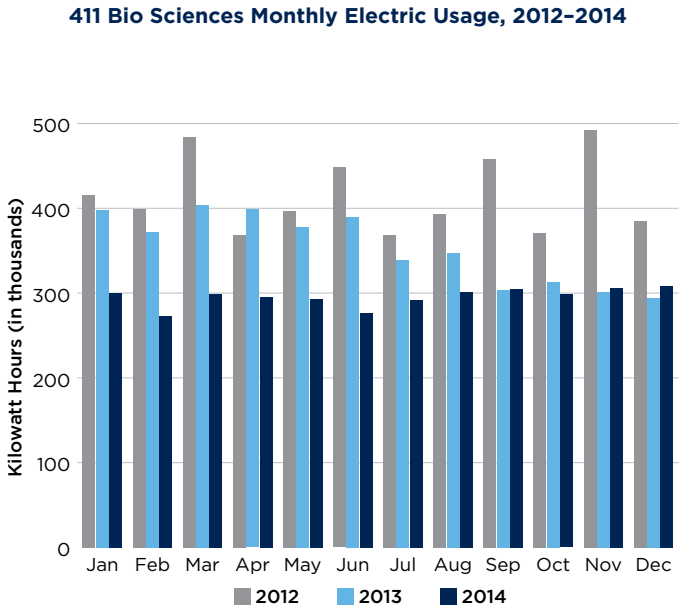
- Weather-normalized annual EUI decreased by 46 percent
- Reduced steam, electricity, and chilled water use
- Annual utility savings of $242,000 on investment of only $450,000
- Greater building occupant comfort

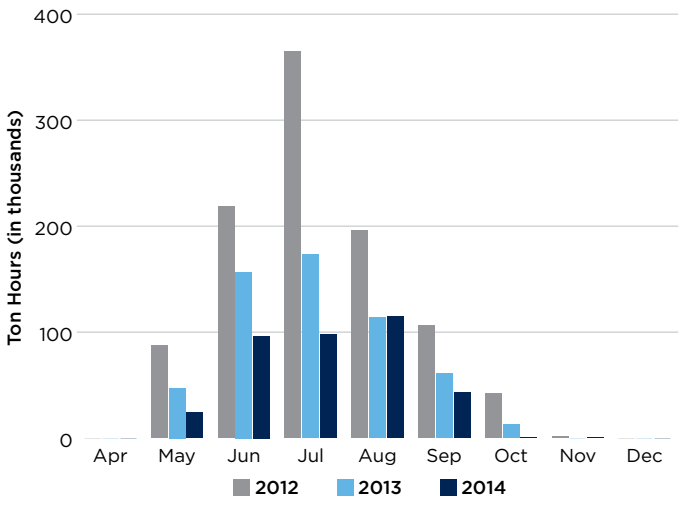
the building during the summer. Prior to retro-commissioning, when the reheat system was on throughout the year, a substantial amount of chilled water was needed to keep the building cool during the summer. Once the reheat system was turned off for the summer, significantly less chilled water was necessary to maintain a comfortable indoor temperature.

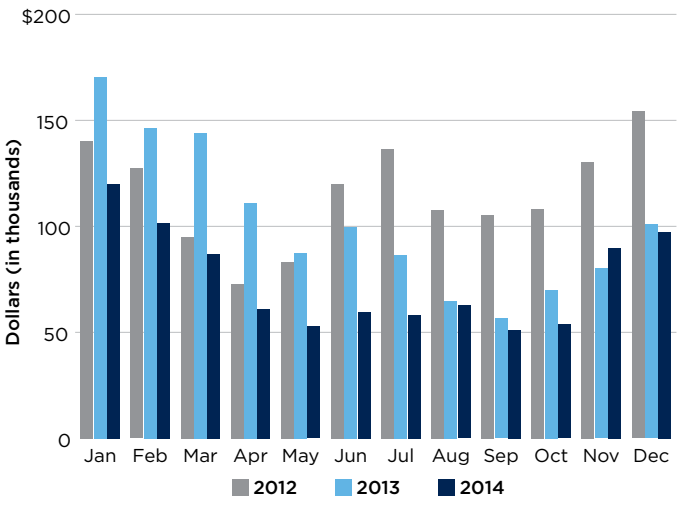
The fourth graph, which displays monthly energy billing, highlights the cost savings realized by decreasing the building's steam, electricity, and chilled water use. Approximately 50 percent of Biological Sciences' overall energy costs can be attributed to steam, 40 percent to electricity, and the remaining 10 percent to chilled water. To ensure that the various retrocommissioning

Figure 4: **Monthly energy usage and cost data from the start of 2012 to the present. Note: the retrocommissioning project began in June 2013.**









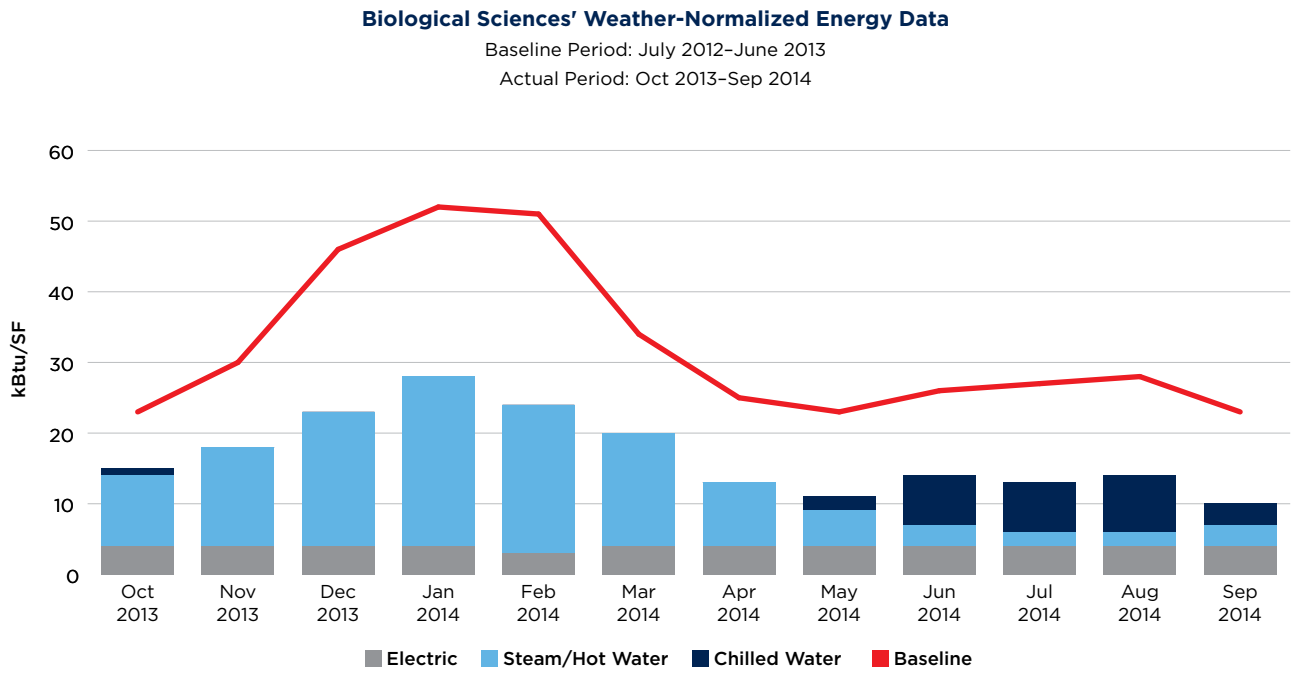


Figure 5: **Biological Sciences' weather-normalized energy consumption data reveals the extensive energy savings achieved as a result of retrocommissioning.**

measures continue to yield the desired energy and cost savings, the Energy Management Group will closely watch for any unexpected, future deviations in the building's monthly energy bills.

It is important to note that the data in the four graphs reflect the year-to-year variability in local temperatures. The University of Minnesota experienced a mild winter in 2012, followed by a normal winter in 2013, and an exceptionally cold winter in 2014. These temperature fluctuations had a significant effect on Biological Sciences' energy performance, and thus to better understand the impact of the retrocommissioning effort it is important to weather normalize the data.

The Energy Management Group uses B3 Benchmarking, an energy management system for public buildings in Minnesota, to weather normalize the energy data for University of Minnesota buildings. Biological Sciences' weather-normalized annual EUI decreased from an average of 339 kBtu/GSF to 183 kBtu/GSF as a result of retrocommissioning, the latter value representing the yearlong period from July 2013 to June 2014. This change equates to an impressive 46 percent reduction in annual EUI and shows that the Energy Management Group achieved its goal of decreasing Biological Sciences' annual EUI below the self-established 200 kBtu/GSF threshold.

Figure 5 shows the weather-normalized energy use data for Biological Sciences. The red line on the graph indicates the building's baseline EUI during the year directly prior to retrocommissioning and the vertical bars represent the monthly EUIs beginning in October 2013, a few months into the retrocommissioning project. Retrocommissioning clearly resulted in substantial energy savings for Biological Sciences, with the most sizable energy reductions occurring during the winter. This is to be expected, as reducing the building's air change rate significantly decreased the amount of energy needed to warm incoming outdoor air during Minnesota's cold winters.

Written by Leonard Kolstad, Institute for Market Transformation.

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Disclaimer

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The Institute for Market Transformation (IMT) is a Washington, DC-based nonprofit organization promoting energy efficiency, green building, and environmental protection in the United States and abroad. IMT's work addresses market failures that inhibit investment in energy efficiency and sustainability in the building sector. For more information, visit imt.org.

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